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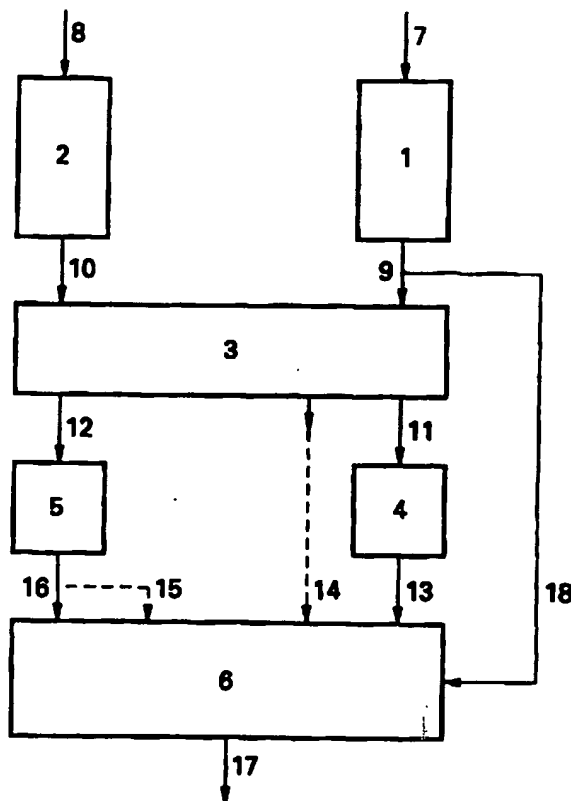
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(54) Title: SIGNAL QUALITY DETERMINING DEVICE AND METHOD

(57) Abstract

A device for determining the quality of an output signal to be generated by a signal processing circuit with respect to a reference signal is provided with a first series circuit for receiving the output signal and with a second series circuit for receiving the reference signal and generates an objective quality signal by means of a combining circuit coupled to the two series circuits. The poor correlation between said objective quality signal and a subjective quality signal to be assessed by human observers can be considerably improved by coupling a converting arrangement to a series circuit for converting at least two signal parameters into a third signal parameter, and by coupling a discounting arrangement to the converting arrangement for discounting the third signal parameter at the combining circuit.



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Signal quality determining device and method

A Background of the invention

The invention relates to a device for determining the quality of an output signal to be generated by a signal processing circuit with respect to a reference signal, which device is provided with a first series circuit having a first input for receiving the output signal and is provided with a second series circuit having a second input for receiving the reference signal and is provided with a combining circuit, coupled to a first output of the first series circuit and to a second output of the second series circuit, for generating a quality signal, which first series circuit is provided with

- a first signal processing arrangement, coupled to the first input of the first series circuit, for generating a first signal parameter as a function of time and frequency, and
- a first compressing arrangement, coupled to the first signal processing arrangement, for compressing a first signal parameter and for generating a first compressed signal parameter, which second series circuit is provided with
- a second compressing arrangement, coupled to the second input, for generating a second compressed signal parameter, which combining circuit is provided with
- a differential arrangement, coupled to the two compressing arrangements, for determining a differential signal on the basis of the compressed signal parameters, and
- an integrating arrangement, coupled to the differential arrangement, for generating the quality signal by integrating the differential signal with respect to time and frequency.

Such a device is disclosed in the first reference: J. Audio Eng. Soc., Vol. 40, No. 12, December 1992, in particular "A Perceptual Audio Quality Measure Based on a Psychoacoustic Sound Representation" by John G. Beerends and Jan A. Stemerdink, pages 963 - 978, more particularly Figure 7. The device described therein determines the quality of an output signal to be generated by a signal processing circuit, such as, for example, a coder/decoder, or codec, with respect to a reference signal. Said reference signal is, for example, an input signal to be presented to the signal processing circuit, although the possibilities also include using as reference signal a pre-calculated

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ideal version of the output signal. The first signal parameter is generated as a function of time and frequency by means of the first signal processing arrangement, associated with the first series circuit, in response to the output signal, after which the first
5 signal parameter is compressed by means of the first compressing arrangement associated with the first series circuit. In this connection, intermediate operational processing of said first signal parameter should not be ruled out at all. The second signal parameter is compressed by means of the second compressing arrangement
10 associated with the second series circuit in response to the reference signal. In this connection, too, further operational processing of said second signal parameter should not be ruled out at all. Of both compressed signal parameters the differential signal is determined by means of the differential arrangement associated with the combining
15 circuit, after which the quality signal is generated by integrating the differential signal with respect to time and frequency by means of the integrating arrangement associated with the combining circuit.

Such a device has, inter alia, the disadvantage that the objective quality signal to be assessed by means of said device and a
20 subjective quality signal to be assessed by human observers have a poor correlation.

B Summary of the invention

The object of the invention is, inter alia, to provide a device
25 of the type mentioned in the preamble, the objective quality signal to be assessed by means of said device and a subjective quality signal to be assessed by human observers having a better correlation.

For this purpose, the device according to the invention has the characteristic that the device comprises

- 30 - a converting arrangement coupled to at least one series circuit for converting at least two signal parameters into a third signal parameter, and
- a discounting arrangement coupled to the converting arrangement for discounting the third signal parameter at the integrating
35 arrangement.

As a result of providing the device with the converting arrangement and the discounting arrangement, the complexity of the reference signal or output signal can be used to adjust the quality

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signal. Due to said converting and discounting, a good correlation is obtained between the objective quality signal to be assessed by means of said device and a subjective quality signal to be assessed by human observers.

5 The invention is based, inter alia, on the insight that the poor correlation between objective quality signals to be assessed by means of known devices and subjective quality signals to be assessed by human observers is the consequence, inter alia, of the fact that
10 certain distortions are found to be more objectionable by human observers than other distortions, which poor correlation is improved by using the two compressing arrangements, and is furthermore based, inter alia, on the insight that distortions in a less complex signal are found to be more objectionable than distortions in a more complex signal.

15 The problem of the poor correlation is thus solved by an improved functioning of the device as a result of providing the device with the converting arrangement and the discounting arrangement.

 A first embodiment of the device according to the invention has the characteristic that the converting arrangement converts at least a
20 signal parameter at a first timepoint and at a first frequency and another signal parameter at a second timepoint and at the first frequency into a fourth signal parameter at the first frequency and converts a further signal parameter at a first timepoint and at a second frequency and another further signal parameter at a second
25 timepoint and at the second frequency into a further fourth signal parameter at the second frequency, the discounting arrangement being situated between the differential arrangement and the integrating arrangement, and the third signal parameter comprising the fourth signal parameter and the further fourth signal parameter.

30 In this case the adjustment is done before the differential signal is integrated with respect to time and frequency.

 A second embodiment of the device according to the invention has the characteristic that the converting arrangement converts at least a
35 signal parameter at a first timepoint and at a first frequency and another signal parameter at the first timepoint and at a second frequency into the third signal parameter at the first timepoint, the discounting arrangement being situated inside the integrating arrangement for discounting the third signal parameter after the

differential signal being integrated with respect to frequency and before the differential signal is integrated with respect to time.

A third embodiment of the device according to the invention has the characteristic that the second series circuit is furthermore
5 provided with

- a second signal processing arrangement, coupled to the second input, for generating a second signal parameter as a function of both time and frequency, the second compressing arrangement being coupled to the second signal processing arrangement in order to compress the
10 second signal parameter.

If the second series circuit is furthermore provided with the second signal processing arrangement, the second signal parameter is generated as a function of both time and frequency. In this case, the input signal to be presented to the signal processing circuit, such
15 as, for example, a coder/decoder, or codec, whose quality is to be determined, is used as reference signal, in contrast to when a second signal processing arrangement is not used, in which case a pre-calculated ideal version of the output signal should be used as reference signal.

20 A fourth embodiment of the device according to the invention has the characteristic that a signal processing arrangement is provided with

- a multiplying arrangement for multiplying in the time domain a signal to be fed to an input of the signal processing arrangement by a
25 window function, and

- a transforming arrangement, coupled to the multiplying arrangement, for transforming a signal originating from the multiplying arrangement to the frequency domain, which transforming arrangement generates, after determining an
30 absolute value, a signal parameter as a function of time and frequency.

In this connection, the signal parameter is generated as a function of time and frequency by the first and/or second signal processing arrangement as a result of using the multiplying
35 arrangement and the transforming arrangement, which transforming arrangement also performs, for example, the absolute-value determination.

A fifth embodiment of the device according to the invention has

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the characteristic that a signal processing arrangement is provided with

- a subband filtering arrangement for filtering a signal to be fed to an input of the signal processing arrangement, which subband filtering arrangement generates, after determining an absolute value, a signal parameter as a function of time and frequency.

In this connection, the signal parameter is generated as a function of time and frequency by the first and/or second signal processing arrangement as a result of using the subband filtering arrangement which also performs, for example, the absolute-value determination.

A sixth embodiment of the device according to the invention has the characteristic that the signal processing arrangement is furthermore provided with

- a converting arrangement for converting a signal parameter represented by means of a time spectrum and a frequency spectrum to a signal parameter represented by means of a time spectrum and a Bark spectrum.

In this connection, the signal parameter generated by the first and/or second signal processing arrangement and represented by means of a time spectrum and a frequency spectrum is converted into a signal parameter represented by means of a time spectrum and a Bark spectrum by using the converting arrangement.

The invention furthermore relates to a method for determining the quality of an output signal to be generated by a signal processing circuit with respect to a reference signal, which method comprises the following steps of

- generating a first signal parameter as a function of time and frequency in response to the output signal,
- compressing a first signal parameter and generating a first compressed signal parameter,
- generating a second compressed signal parameter in response to the reference signal,
- determining a differential signal on the basis of the compressed signal parameters, and
- generating a quality signal by integrating the differential signal with respect to time and frequency.

The method according to the invention has the characteristic

that the method furthermore comprises the following steps of

- converting at least two signal parameters into a third signal parameter, and
- discounting the third signal parameter after determination of the differential signal and before generation of the quality signal.

A first embodiment of the method according to the invention has the characteristic that the method comprises the following steps of

- converting at least a signal parameter at a first timepoint and at a first frequency and another signal parameter at a second timepoint and at the first frequency into a fourth signal parameter at the first frequency,
- converting a further signal parameter at a first timepoint and at a second frequency and another further signal parameter at a second timepoint and at the second frequency into a further fourth signal parameter at the second frequency, and
- discounting the third signal parameter comprising the fourth signal parameter and the further fourth signal parameter before the differential signal is integrated with respect to time and frequency.

A second embodiment of the method according to the invention has the characteristic that the method comprises the following steps of

- converting at least a signal parameter at a first timepoint and at a first frequency and another signal parameter at the first timepoint and at a second frequency into the third signal parameter at the first timepoint, and
- discounting the third signal parameter after the differential signal has been integrated with respect to frequency and before the differential signal is integrated with respect to time.

A third embodiment of the method according to the invention has the characteristic that the step of generating a second compressed signal parameter in response to the reference signal comprises the following two steps of

- generating a second signal parameter in response to the reference signal as a function of both time and frequency, and
- compressing a second signal parameter.

A fourth embodiment of the method according to the invention has the characteristic that the step of generating a first signal parameter in response to the output signal as a function of time and frequency comprises the following two steps of

- multiplying in the time domain a still further first signal to be generated in response to the output signal by a window function, and

5 - transforming the still further first signal to be multiplied by the window function to the frequency domain, which represents, after determining an absolute value, a signal parameter as a function of time and frequency.

A fifth embodiment of the method according to the invention has the characteristic that the step of generating a first signal
10 parameter in response to the output signal as a function of time and frequency comprises the following step of

- filtering a still further first signal to be generated in response to the output signal, which represents, after determining an absolute value, a signal parameter as a function of time and
15 frequency.

A sixth embodiment of the method according to the invention has the characteristic that the step of generating a first signal parameter in response to the output signal as a function of time and frequency also comprises the following step of
20 - converting a signal parameter represented by means of a time spectrum and a frequency spectrum to a signal parameter represented by means of a time spectrum and a Bark spectrum.

C References

25 ■ J. Audio Eng. Soc., Vol. 40, No. 12, December 1992, in particular, "A Perceptual Audio Quality Measure Based on a Psychoacoustic Sound Representation" by John G. Beerends and Jan A. Stemerdink, pages 963 - 978

30 ■ "Modelling a Cognitive Aspect in the Measurement of the Quality of Music Codecs", by John G. Beerends and Jan A. Stemerdink, presented at the 96th Convention 26 February - 1 March 1994, Amsterdam

35 ■ US 4,860,360

■ EP 0 627 727

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■ DE 37 08 002

5 ■ NL 9500512 (Dutch priority patent application)

All the references including the literature cited in these references are deemed to be incorporated in this patent application.

10 D Exemplary embodiment

The invention will be explained in greater detail by reference to an exemplary embodiment shown in the figures. In the figures:

Figure 1 shows a device according to the invention, comprising known signal processing arrangements, known compressing arrangements, and a combining circuit according to the invention,

15 Figure 2 shows a known signal processing arrangement for use in the device according to the invention,

Figure 3 shows a known compressing arrangement for use in the device according to the invention,

20 Figure 4 shows a scaling circuit for use in the device according to the invention, and

Figure 5 shows a combining circuit according to the invention for use in the device according to the invention.

The device according to the invention shown in Figure 1 comprises a first signal processing arrangement 1 having a first input 7 for receiving an output signal originating from a signal processing circuit such as, for example, a coder/decoder, or codec. A first output of first signal processing arrangement 1 is connected via a coupling 9 to a first input of a scaling circuit 3. The device according to the invention furthermore comprises a second signal processing arrangement 2 having a second input 8 for receiving an input signal to be fed to the signal processing circuit such as, for example, the coder/decoder, or codec. A second output of second signal processing arrangement 2 is connected via a coupling 10 to a second input of scaling circuit 3. A first output of scaling circuit 3 is connected via a coupling 11 to a first input of a first compressing arrangement 4, and a second output of scaling circuit 3 is connected via a coupling 12 to a second input of a second compressing

arrangement 5. A first output of first compressing arrangement 4 is connected via a coupling 13 to a first input of a combining circuit 6, and a second output of second compressing arrangement 5 is connected via a coupling 16 to a second input of combining circuit 6. A third output of scaling circuit 3 is connected via a coupling 14 to a third input of combining circuit 6, and the second output of second compressing arrangement 5, or coupling 16, is connected via a coupling 15 to a fourth input of combining circuit 6 which has an output 17 for generating a quality signal. The first output of first signal processing arrangement 1 is connected via a coupling 18 to a fifth input of combining circuit 6. First signal processing arrangement 1 and first compressing arrangement 4 jointly correspond to a first series circuit, and second signal processing arrangement 2 and second compressing arrangement 5 jointly correspond to a second series circuit.

The known first (or second) signal processing arrangement 1 (or 2) shown in Figure 2 comprises a first (or second) multiplying arrangement 20 for multiplying in the time domain the output signal (or input signal) to be fed to the first input 7 (or second input 8) of the first (or second) signal processing arrangement 1 (or 2) and originating from the signal processing circuit such as, for example, the coder/decoder, or codec, by a window function, a first (or second) transforming arrangement 21, coupled to the first (or second) multiplying arrangement 20, for transforming the signal originating from the first (or second) multiplying arrangement 20 to the frequency domain, a first (or second) absolute-value arrangement 22 for determining the absolute value of the signal originating from the first (or second) transforming arrangement 21 for generating a first (or second) positive signal parameter as a function of time and frequency, a first (or second) converting arrangement 23 for converting the first (or second) positive signal parameter originating from the first (or second) absolute-value arrangement 22 and represented by means of a time spectrum and a frequency spectrum into a first (or second) signal parameter represented by means of a time spectrum and a Bark spectrum, and a first (or second) discounting arrangement 24 for discounting a hearing function in the case of the first (or second) signal parameter originating from the first (or second) converting arrangement and represented by means of a time

spectrum and a Bark spectrum, which signal parameter is then transmitted via the coupling 9 (or 10).

The known first (or second) compressing arrangement 4 (or 5) shown in Figure 3 receives via coupling 11 (or 12) a signal parameter which is fed to a first (or second) input of a first (or second) adder 30, a first (or second) output of which is connected via a coupling 31, on the one hand, to a first (or second) input of a first (or second) multiplier 32 and, on the other hand, to a first (or second) nonlinear convoluting arrangement 36 which is furthermore connected to a first (or second) compressing unit 37 for generating via coupling 13 (or 16) a first (or second) compressed signal parameter. First (or second) multiplier 32 has a further first (or second) input for receiving a feed signal and has a first (or second) output which is connected to a first (or second) input of a first (or second) delay arrangement 34, a first (or second) output of which is coupled to a further first (or second) input of the first (or second) adder 30.

The scaling circuit 3 shown in Figure 4 comprises a further integrating arrangement 40, a first input of which is connected to the first input of scaling circuit 3 and consequently to coupling 9 for receiving a first series circuit signal (the first signal parameter represented by means of a time spectrum and a Bark spectrum) and a second input of which is connected to the second input of scaling circuit 3 and consequently to coupling 10 for receiving a second series circuit signal (the second signal parameter represented by means of a time spectrum and a Bark spectrum). A first output of further integrating arrangement 40 for generating the integrated first series circuit signal is connected to a first input of a comparing arrangement 41 and a second output of further integrating arrangement 40 for generating the integrated second series circuit signal is connected to a second input of comparing arrangement 41. The first input of scaling circuit 3 is connected to the first output and, via scaling circuit 3, coupling 9 is consequently connected through to coupling 11. The second input of scaling circuit 3 is connected to a first input of a further scaling unit 42 and a second output is connected to an output of further scaling unit 42 and, via scaling circuit 3, coupling 10 is consequently connected through to coupling 12 via further scaling unit 42. An output of comparing arrangement 41 for generating a control signal is connected to a control input of

further scaling unit 42. The first input of scaling circuit 3, or coupling 9 or coupling 11, is connected to a first input of a ratio-determining arrangement 43 and the output of further scaling unit 42, or coupling 12, is connected to a second input of ratio-determining arrangement 43, an output of which is connected to the third output of scaling circuit 3 and consequently to coupling 14 for generating a further scaling signal.

The combining circuit 6 shown in Figure 5 comprises a further comparing arrangement 50, a first input of which is connected to the first input of combining circuit 6 for receiving the first compressed signal parameter via coupling 13 and a second input of which is connected to the second input of combining circuit 6 for receiving the second compressed signal parameter via coupling 16. The first input of combining circuit 6 is furthermore connected to a first input of a differential arrangement 54,56. An output of further comparing arrangement 50 for generating a scaling signal is connected via a coupling 51 to a control input of scaling arrangement 52, an input of which is connected to the second input of combining circuit 6 for receiving the second compressed signal parameter via coupling 16 and an output of which is connected via a coupling 53 to a second input of differential arrangement 54,56 for determining a differential signal on the basis of the mutually scaled compressed signal parameters. A third input of the differential arrangement 54,56 is connected to the fourth input of the combining circuit 6 for receiving, via coupling 15, the second compressed signal parameter to be received via coupling 16. Differential arrangement 54,56 comprises a differentiator 54 for generating a differential signal and a further absolute-value arrangement 56 for determining the absolute value of the differential signal, an output of which is connected to an input of scaling unit 57, a control input of which is connected to the third input of combining circuit 6 for receiving the further scaling signal via coupling 14. An output of scaling unit 57 is connected to an input of discounting arrangement 61, of which a control input is coupled to an output of converting arrangement 60. An input of converting arrangement 60 is coupled to the fifth input of combining circuit 6 for receiving at least two signal parameters and converting them into a third signal parameter. An output of discounting arrangement 61 is connected to an input of an integrating arrangement 58,59 for

integrating the scaled absolute value of the differential signal with respect to time and frequency. Integrating arrangement 58,59 comprises a series arrangement of an integrator 58 and a time-averaging arrangement 59, an output of which is connected to the output 17 of combining circuit 6 for generating the quality signal.

The operation of a known device for determining the quality of the output signal to be generated by the signal processing circuit such as, for example, the coder/decoder, or codec, which known device is formed without the scaling circuit 3 shown in greater detail in Figure 4, the couplings 10 and 12 consequently being mutually connected through, and which known device is formed using a standard combining circuit 6, the third input, shown in greater detail in Figure 5, of differential arrangement 54,56, and scaling unit 57, and discounting arrangement 61 and converting arrangement 60 consequently being missing, is as follows and, indeed, as also described in the first reference.

The output signal of the signal processing circuit such as, for example, the coder/decoder, or codec, is fed to input 7, after which the first signal processing circuit 1 converts said output signal into a first signal parameter represented by means of a time spectrum and a Bark spectrum. This takes place by means of the first multiplying arrangement 20 which multiplies the output signal represented by means of a time spectrum by a window function represented by means of a time spectrum, after which the signal thus obtained and represented by means of a time spectrum is transformed by means of first transforming arrangement 21 to the frequency domain, for example by means of an FFT, or fast Fourier transform, after which the absolute value of the signal thus obtained and represented by means of a time spectrum and a frequency spectrum is determined by means of the first absolute-value arrangement 22, for example by squaring, after which the signal parameter thus obtained and represented by means of a time spectrum and a frequency spectrum is converted by means of first converting arrangement 23 into a signal parameter represented by means of a time spectrum and a Bark spectrum, for example by resampling on the basis of a nonlinear frequency scale, also referred to as Bark scale, which signal parameter is then adjusted by means of first discounting arrangement 24 to a hearing function, or is filtered, for example by multiplying by a characteristic represented by means of a Bark

spectrum.

The first signal parameter thus obtained and represented by means of a time spectrum and a Bark spectrum is then converted by means of the first compressing arrangement 4 into a first compressed
5 signal parameter represented by means of a time spectrum and a Bark spectrum. This takes place by means of first adder 30, first multiplier 32 and first delay arrangement 34, the signal parameter represented by means of a time spectrum and a Bark spectrum being multiplied by a feed signal represented by means of a Bark spectrum
10 such as, for example, an exponentially decreasing signal, after which the signal parameter thus obtained and represented by means of a time spectrum and a Bark spectrum is added, with a delay in time, to the signal parameter represented by means of a time spectrum and a Bark spectrum, after which the signal parameter thus obtained and
15 represented by means of a time spectrum and a Bark spectrum is convoluted by means of first nonlinear convoluting arrangement 36 with a spreading function represented by means of a Bark spectrum, after which the signal parameter thus obtained and represented by means of a time spectrum and a Bark spectrum is compressed by means of first
20 compressing unit 37.

In a corresponding manner, the input signal of the signal processing circuit such as, for example, the coder/decoder, or codec, is fed to input 8, after which the second signal processing circuit 2 converts said input signal into a second signal parameter represented
25 by means of a time spectrum and a Bark spectrum, and the latter is converted by means of the second compressing arrangement 5 into a second compressed signal parameter represented by means of a time spectrum and a Bark spectrum.

The first and second compressed signal parameters, respectively,
30 are then fed via the respective couplings 13 and 16 to combining circuit 6, it being assumed for the time being that this is a standard combining circuit which lacks the third input of differential arrangement 54, 56, and scaling unit 57, and discounting arrangement 61 and converting arrangement 60 shown in greater detail in Figure 5. The
35 two compressed signal parameters are integrated by further comparing arrangement 50 and mutually compared, after which further comparing arrangement 50 generates the scaling signal which represents, for example, the average ratio between the two compressed signal

parameters. Said scaling signal is fed to scaling arrangement 52 which, in response thereto, scales the second compressed signal parameter (that is to say, increases or reduces it as a function of the scaling signal). Obviously, scaling arrangement 52 could also be
5 used, in a manner known to the person skilled in the art, for scaling the first compressed signal parameter instead of for scaling the second compressed signal parameter and use could furthermore be made, in a manner known to the person skilled in the art, of two scaling
10 arrangements for mutually scaling the two compressed signal parameters at the same time. The differential signal is derived by means of differentiator 54 from the mutually scaled compressed signal parameters, the absolute value of which differential signal is then determined by means of further absolute-value arrangement 56. The
15 signal thus obtained is integrated by means of integrator 58 with respect to a Bark spectrum and is integrated by means of time-averaging arrangement 59 with respect to a time spectrum and generated by means of output 17 as quality signal which indicates in an objective manner the quality of the signal processing circuit such as, for example, the coder/decoder or codec.

20 The operation of the device according to the invention for determining the quality of the output signal to be generated by the signal processing circuit such as, for example, the coder/decoder, or codec, which device according to the invention is consequently formed with the scaling circuit 3 shown in greater detail in Figure 4, the
25 couplings 10 and 12 consequently being coupled through mutually via further scaling unit, and which known device is formed with an expanded combining circuit 6 according to the invention to which the third input of differential arrangement 54,56 shown in greater detail in Figure 5, and scaling unit 57, and discounting arrangement 61 and
30 converting arrangement 60 have consequently been added is as described above, supplemented by what follows.

The first series circuit signal (the first signal parameter represented by means of a time spectrum and a Bark spectrum) to be received via coupling 9 and the first input of scaling circuit 3 is
35 fed to the first input of further integrating arrangement 40 and the second series circuit signal (the second signal parameter represented by means of a time spectrum and a Bark spectrum) to be received via the coupling 10 and the second input of scaling circuit 3 is fed to

the second input of further integrating arrangement 40, which integrates the two series circuit signals with respect to frequency, after which the integrated first series circuit signal is fed via the first output of further integrating arrangement 40 to the first input of comparing arrangement 41 and the integrated second series circuit signal is fed via the second output of further integrating arrangement 40 to the second input of comparing arrangement 41. The latter compares the two integrated series circuit signals and generates, in response thereto, the control signal which is fed to the control input of further scaling unit 42. The latter scales the second series circuit signal (the second signal parameter represented by means of a time spectrum and a Bark spectrum) to be received via coupling 10 and the second input of scaling circuit 3 as a function of said control signal (that is to say increases or reduces the amplitude of said second series circuit signal) and generates the thus scaled second series circuit signal via the output of further scaling unit 42 to the second output of scaling circuit 3, while the first input of scaling arrangement 3 is connected through in this example in a direct manner to the first output of scaling circuit 3. In this example, the first series circuit signal and the scaled second series circuit signal, respectively are passed via scaling circuit 3 to first compressing arrangement 4 and second compressing arrangement 5, respectively.

As a result of this further scaling, a good correlation is obtained between the objective quality signal to be assessed by means of the device according to the invention and a subjective quality signal to be assessed by human observers. This all is based, inter alia, on the insight that the poor correlation between objective quality signals to be assessed by means of known devices and subjective quality signals to be assessed by human observers is the consequence, inter alia, of the fact that certain distortions are found to be more objectionable by human observers than other distortions, which poor correlation is improved by using the two compressing arrangements, and is furthermore based, inter alia, on the insight that, as a result of using scaling circuit 3, the two compressing arrangements 4 and 5 function better with respect to one another, which improves the correlation further. So, the problem of the poor correlation can be solved by an improved functioning of the two compressing arrangements 4 and 5 with respect to one another as a

result of using scaling circuit 3.

As a result of the fact that the first input of scaling circuit 3, or coupling 9 or coupling 11, is connected to the first input of ratio-determining arrangement 43 and the output of further scaling unit 42, or coupling 12, is connected to the second input of ratio-determining arrangement 43, ratio-determining arrangement 43 is capable of assessing the mutual ratio of the first series circuit signal and the scaled second series circuit signal and of generating a further scaling signal as a function thereof by means of the output of ratio-determining arrangement 43, which further scaling signal is fed via the third output of scaling circuit 3 and consequently via coupling 14 to the third input of combining circuit 6. Said further scaling signal is fed in combining circuit 6 to scaling unit 57 which scales, as a function of said further scaling signal, the absolute value of the differential signal originating from the differential arrangement 54,56 (that is to say increases or reduces the amplitude of said absolute value). As a consequence thereof, the already improved correlation is improved further as a result of the fact an (amplitude) difference still present between the first series circuit signal and the scaled second series circuit signal in the combining circuit is discounted and integrating arrangement 58,59 functions better as a result.

A further improvement of the correlation is obtained if differentiator 54 (or further absolute-value arrangement 56) is provided with a further adjusting arrangement, not shown in the figures, for example in the form of a subtracting circuit which somewhat reduces the amplitude of the differential signal. Preferably, the amplitude of the differential signal is reduced as a function of a series circuit signal, just as in this example it is reduced as a function of the scaled and compressed second signal parameter originating from second compressing arrangement 5, as a result of which integrating arrangement 58,59 functions still better. As a result, the already very good correlation is improved still further.

Another further improvement of the correlation is obtained if combining circuit 6 is provided with discounting arrangement 61, of which a control input is coupled to the first and/or second series circuit via converting arrangement 60. In case of converting arrangement 60 being coupled to the first series circuit, the first

signal parameters originating from first signal processing circuit 1 are supplied to the input of converting arrangement 60. These first signal parameters are represented by means of a time spectrum and a frequency spectrum (in particular a Bark spectrum). Table 1 shows sixteen first signal parameters X , each one at one out of four timepoints t_1 - t_4 and at one out of four frequencies f_1 - f_4 :

table 1	t_1	t_2	t_3	t_4
f_1	$X_{t1,f1}$	$X_{t2,f1}$	$X_{t3,f1}$	$X_{t4,f1}$
f_2	$X_{t1,f2}$	$X_{t2,f2}$	$X_{t3,f2}$	$X_{t4,f2}$
f_3	$X_{t1,f3}$	$X_{t2,f3}$	$X_{t3,f3}$	$X_{t4,f3}$
f_4	$X_{t1,f4}$	$X_{t2,f4}$	$X_{t3,f4}$	$X_{t4,f4}$

According to a first embodiment (discounting arrangement 61 is situated between differential arrangement 54,56 and integrator 58), converting arrangement 60 converts for example the four signal parameters $X_{t1,f1}$, $X_{t2,f1}$, $X_{t3,f1}$, $X_{t4,f1}$ into a fourth signal parameter Y_{f1} , and converts the four signal parameters $X_{t1,f2}$, $X_{t2,f2}$, $X_{t3,f2}$, $X_{t4,f2}$ into a further fourth signal parameter Y_{f2} , and converts the four signal parameters $X_{t1,f3}$, $X_{t2,f3}$, $X_{t3,f3}$, $X_{t4,f3}$ into a still further fourth signal parameter Y_{f3} , and converts the four signal parameters $X_{t1,f4}$, $X_{t2,f4}$, $X_{t3,f4}$, $X_{t4,f4}$ into a yet still further fourth signal parameter Y_{f4} . This converting is for example realised by calculating the average value of each four signal parameters, and then taking the absolute difference between the last one of each four signal parameters and the corresponding average value. The four fourth signal parameters are supplied to the control input of discounting arrangement 61. At its input discounting arrangement 61 receives the differential signal comprising four parameters $Z_{t4,f1}$, $Z_{t4,f2}$, $Z_{t4,f3}$, $Z_{t4,f4}$, and generates at its output these four signal parameters, each one being divided by the corresponding fourth signal parameter: $Z_{t4,f1}/Y_{f1}$, $Z_{t4,f2}/Y_{f2}$, $Z_{t4,f3}/Y_{f3}$, $Z_{t4,f4}/Y_{f4}$.

According to a second embodiment (discounting arrangement 61 should be situated between integrator 58 and time-averaging arrangement 59), converting arrangement 60 converts for example the

four signal parameters $X_{t4,f1}$, $X_{t4,f2}$, $X_{t4,f3}$, $X_{t4,f4}$ into a third signal parameter W_{t4} . This converting is for example realised by calculating the average value of these four signal parameters, then calculating the difference between each one of these four signal parameters and the average value, squaring each calculated difference, summing the squared calculated differences and rooting this sum, the rooted sum being equal to the third signal parameter W_{t4} . This third signal parameter is supplied to the control input of discounting arrangement 61. At its input discounting arrangement 61 receives a signal V_{t4} coming from integrator 58, and generates at its output this signal, being divided by the third signal parameter: V_{t4}/W_{t4} .

According to a third embodiment (discounting arrangement 61 should be situated between integrator 58 and time-averaging arrangement 59), converting arrangement 60 converts for example the four signal parameters $X_{t4,f1}$, $X_{t4,f2}$, $X_{t4,f3}$, $X_{t4,f4}$ into a third signal parameter W_{t4} . This converting is for example realised by calculating the average value of Y_{f1} , Y_{f2} , Y_{f3} , Y_{f4} , then calculating the difference between each one of these four signal parameters $X_{t4,f1}$, $X_{t4,f2}$, $X_{t4,f3}$, $X_{t4,f4}$ and the average value, squaring each calculated difference, summing the squared calculated differences and rooting this sum, the rooted sum being equal to the third signal parameter W_{t4} . This third signal parameter is supplied to the control input of discounting arrangement 61. At its input discounting arrangement 61 receives a signal V_{t4} coming from integrator 58, and generates at its output this signal, being divided by the third signal parameter: V_{t4}/W_{t4} .

As a result of providing the device with converting arrangement 60 and discounting arrangement 61, the complexity of the reference signal or output signal can be used to adjust the quality signal. Due to said converting and discounting, a good correlation is obtained between the objective quality signal to be assessed by means of said device and a subjective quality signal to be assessed by human observers. The invention is based, inter alia, on the insight that the poor correlation between objective quality signals to be assessed by means of known devices and subjective quality signals to be assessed by human observers is the consequence, inter alia, of the fact that certain distortions are found to be more objectionable by human observers than other distortions, which poor correlation is improved by using the two compressing arrangements, and is furthermore based,

inter alia, on the insight that distortions in a less complex signal are found to be more objectionable than distortions in a more complex signal.

Usually discounting arrangement 61 and converting arrangement 60 will be situated inside combining circuit 6. However, converting arrangement 60 could for example also be placed inside one of the series circuits. Although in figure 1 the fifth input of combining circuit 6 is coupled to the first series circuit (the first output of first signal processing arrangement 1), this fifth input could also be coupled to the second series circuit (for example the second output of second signal processing circuit 2). Recent proof shows that this will improve the correlation even more.

The components shown in Figure 2 of first signal processing arrangement 1 are described, as stated earlier, adequately and in a manner known to the person skilled in the art in the first reference. A digital output signal which originates from the signal processing circuit such as, for example, the coder/decoder, or codec, and which is, for example, discrete both in time and in amplitude is multiplied by means of first multiplying arrangement 20 by a window function such as, for example, a so-called cosine square function represented by means of a time spectrum, after which the signal thus obtained and represented by means of a time spectrum is transformed by means of first transforming arrangement 21 to the frequency domain, for example by an FFT, or fast Fourier transform, after which the absolute value of the signal thus obtained and represented by means of a time spectrum and a frequency spectrum is determined by means of the first absolute-value arrangement 22, for example by squaring. Finally, a power density function per time/frequency unit is thus obtained. An alternative way of obtaining said signal is to use a subband filtering arrangement for filtering the digital output signal, which subband filtering arrangement generates, after determining an absolute value, a signal parameter as a function of time and frequency in the form of the power density function per time/frequency unit. First converting arrangement 23 converts said power density function per time/frequency unit, for example by resampling on the basis of a nonlinear frequency scale, also referred to as Bark scale, into a power density function per time/Bark unit, which conversion is described comprehensively in Appendix A of the first reference, and first discounting arrangement

24 multiplies said power density function per time/Bark unit, for example by a characteristic, represented by means of a Bark spectrum, for performing an adjustment on a hearing function.

The components, shown in Figure 3, of first compressing arrangement 4 are, as stated earlier, described adequately and in a manner known to the person skilled in the art in the first reference. The power density function per time/Bark unit adjusted to a hearing function is multiplied by means of multiplier 32 by an exponentially decreasing signal such as, for example, $\exp[-T/\tau(z)]$. Here T is equal to 50% of the length of the window function and consequently represents half of a certain time interval, after which certain time interval first multiplying arrangement 20 always multiplies the output signal by a window function represented by means of a time spectrum (for example, 50% of 40 msec is 20 msec). In this expression, $\tau(z)$ is a characteristic which is represented by means of the Bark spectrum and is shown in detail in Figure 6 of the first reference. First delay arrangement 34 delays the product of this multiplication by a delay time of length T, or half of the certain time interval. First nonlinear convolution arrangement 36 convolutes the signal supplied by a spreading function represented by means of a Bark spectrum, or spreads a power density function represented per time/Bark unit along a Bark scale, which is described comprehensively in Appendix B of the first reference. First compressing unit 37 compresses the signal supplied in the form of a power density function represented per time/Bark unit with a function which, for example, raises the power density function represented per time/Bark unit to the power α , where $0 < \alpha < 1$.

The components, shown in Figure 4, of scaling circuit 3 can be formed in a manner known to the person skilled in the art. Further integrating arrangement 40 comprises, for example, two separate integrators which separately integrate the two series circuit signals supplied by means of a Bark spectrum, after which comparing arrangement 41 in the form of, for example, a divider, divides the two integrated signals by one another and feeds the division result or the inverse division result as control signal to further scaling unit 42 which, in the form of, for example, a multiplier or a divider, multiplies or divides the second series circuit signal by the division result or the inverse division result in order to make the two series

circuit signals, viewed on average, of equal size. Ratio-determining arrangement 43 receives the first and the scaled second series circuit signal in the form of compressed, spread power density functions represented per time/Bark unit and divides them by one another to
5 generate the further scaling signal in the form of the division result represented per time/Bark unit or the inverse thereof, depending on whether scaling unit 57 is constructed as multiplier or as divider.

The components, shown in Figure 5, of first combining circuit 6 are, as stated earlier, described adequately and in a manner known to
10 the person skilled in the art in the first reference, with the exception of the component 57 and a portion of component 54. Further comparing arrangement 50 comprises, for example, two separate integrators which separately integrate the two series circuit signals supplied over, for example, three separate portions of a Bark spectrum
15 and comprises, for example, a divider which divides the two integrated signals by one another per portion of the Bark spectrum and feeds the division result or the inverse division result as scaling signal to scaling arrangement 52 which, in the form of, for example, a multiplier or a divider, multiplies or divides the respective series
20 circuit signal by the division result or the inverse division result in order to make the two series circuit signals, viewed on average, of equal size per portion of the Bark spectrum. All this is described comprehensively in Appendix F of the first reference. Differentiator
25 54 determines the difference between the two mutually scaled series circuit signals. According to the invention, if the difference is negative, said difference can then be augmented by a constant value and, if the difference is positive, said difference can be reduced by a constant value, for example by detecting whether it is less or
30 greater than the value zero and then adding or subtracting the constant value. It is, however, also possible first to determine the absolute value of the difference by means of further absolute-value arrangement 56 and then to deduct the constant value from said absolute value, in which connection a negative final result must obviously not be permitted to be obtained. In this last case,
35 absolute-value arrangement 56 should be provided with a subtracting circuit. Furthermore, it is possible, according to the invention, to discount from the difference a (portion of a) series circuit signal in a similar manner instead of the constant value or together with the

constant value. Integrator 58 integrates the signal originating from scaling unit 57 with respect to a Bark spectrum and time-averaging arrangement 59 integrates the signal thus obtained with respect to a time spectrum, as a result of which the quality signal is obtained
5 which has a value which is the smaller, the higher the quality of the signal processing circuit is.

As already described earlier, the correlation between the objective quality signal to be assessed by means of the device according to the invention and a subjective quality signal to be
10 assessed by human observers is improved by several factors which can be viewed separately from one another:

- the use of discounting arrangement 61 and converting arrangement 60, discounting arrangement 61 being situated between differential arrangement 54,56 and integrating arrangement 58,59,
- 15 - the use of discounting arrangement 61 and converting arrangement 60, discounting arrangement 61 being situated between integrator 58 and time-averaging arrangement 59,
- the use of the scaling circuit 3 without making use of the ratio-determining arrangement 43 and scaling unit 57,
- 20 - the use of the scaling circuit 3 with use being made of ratio-determining arrangement 43 and scaling unit 57,
- the use of differential arrangement 54,56 which is provided with the third input for receiving a signal having a certain value, which signal should be deducted from the difference to be determined
25 originally, and
- the use of differential arrangement 54,56 which is provided with the third input for receiving a further signal derived from a series circuit signal having a further certain value, which further signal should be deducted from the difference to be determined originally.
- 30 - The best correlation is obtained by simultaneous use of several possibilities.

The widest meaning should be reserved for the term signal processing circuit, in which connection, for example, all kinds of audio and/or video equipment can be considered. Thus, the signal
35 processing circuit could be a codec, in which case the input signal is the reference signal with respect to which the quality of the output signal should be determined. The signal processing circuit could also be an equalizer, in which connection the quality of the output signal

should be determined with respect to a reference signal which is calculated on the basis of an already existing virtually ideal equalizer or is simply calculated. The signal processing circuit could even be a loudspeaker, in which case a smooth output signal could be used as reference signal, with respect to which the quality of a sound output signal is then determined (scaling already takes place automatically in the device according to the invention). The signal processing circuit could furthermore be a loudspeaker computer model which is used to design loudspeakers on the basis of values to be set in the loudspeaker computer model, in which connection a low-volume output signal of said loudspeaker computer model serves as the reference signal and in which connection a high-volume output signal of said loudspeaker computer model then serves as the output signal of the signal processing circuit.

15 In the case of a calculated reference signal, the second signal processing arrangement of the second series circuit could be omitted as a result of the fact that the operations to be performed by the second signal processing arrangement can be discounted in calculating the reference signal. In that case, the reference signal could be supplied to converting arrangement 60 as well.

E Claims

1. Device for determining the quality of an output signal to be generated by a signal processing circuit with respect to a reference signal, which device is provided with a first series circuit having a first input for receiving the output signal and is provided with a
5 second series circuit having a second input for receiving the reference signal and is provided with a combining circuit, coupled to a first output of the first series circuit and to a second output of the second series circuit, for generating a quality signal, which first series circuit is provided with
- 10 - a first signal processing arrangement, coupled to the first input of the first series circuit, for generating a first signal parameter as a function of time and frequency, and
- a first compressing arrangement, coupled to the first signal processing arrangement, for compressing a first signal parameter and
15 for generating a first compressed signal parameter, which second series circuit is provided with
- a second compressing arrangement, coupled to the second input, for generating a second compressed signal parameter, which combining circuit is provided with
- 20 - a differential arrangement, coupled to the two compressing arrangements, for determining a differential signal on the basis of the compressed signal parameters, and
- an integrating arrangement, coupled to the differential arrangement, for generating the quality signal by integrating the
25 differential signal with respect to time and frequency, characterized in that the device comprises
- a converting arrangement coupled to at least one series circuit for converting at least two signal parameters into a third signal parameter, and
30 - a discounting arrangement coupled to the converting arrangement for discounting the third signal parameter at the integrating arrangement.
2. Device according to Claim 1, characterized in that the converting arrangement converts at least a signal parameter at a first
35 timepoint and at a first frequency and another signal parameter at a second timepoint and at the first frequency into a fourth signal parameter at the first frequency and converts a further signal

parameter at a first timepoint and at a second frequency and another further signal parameter at a second timepoint and at the second frequency into a further fourth signal parameter at the second frequency, the discounting arrangement being situated between the differential arrangement and the integrating arrangement, and the third signal parameter comprising the fourth signal parameter and the further fourth signal parameter.

3. Device according to Claim 1, characterized in that the converting arrangement converts at least a signal parameter at a first timepoint and at a first frequency and another signal parameter at the first timepoint and at a second frequency into the third signal parameter at the first timepoint, the discounting arrangement being situated inside the integrating arrangement for discounting the third signal parameter after the differential signal being integrated with respect to frequency and before the differential signal is integrated with respect to time.

4. Device according to Claim 1, 2 or 3, characterized in that the second series circuit is furthermore provided with

- a second signal processing arrangement, coupled to the second input, for generating a second signal parameter as a function of both time and frequency, the second compressing arrangement being coupled to the second signal processing arrangement in order to compress the second signal parameter.

5. Device according to Claim 1, 2, 3 or 4, characterized in that a signal processing arrangement is provided with

- a multiplying arrangement for multiplying in the time domain a signal to be fed to an input of the signal processing arrangement by a window function, and
- a transforming arrangement, coupled to the multiplying arrangement, for transforming a signal originating from the multiplying arrangement to the frequency domain, which transforming arrangement generates, after determining an absolute value, a signal parameter as a function of time and frequency.

6. Device according to Claim 1, 2, 3 or 4, characterized in that a signal processing arrangement is provided with

- a subband filtering arrangement for filtering a signal to be fed to an input of the signal processing arrangement,

which subband filtering arrangement generates, after determining an absolute value, a signal parameter as a function of time and frequency.

7. Device according to Claim 5 or 6, characterized in that the
5 signal processing arrangement is furthermore provided with
- a converting arrangement for converting a signal parameter represented by means of a time spectrum and a frequency spectrum into a signal parameter represented by means of a time spectrum and a Bark spectrum.
- 10 8. Method for determining the quality of an output signal to be generated by a signal processing circuit with respect to a reference signal, which method comprises the following steps of
- generating a first signal parameter as a function of time and frequency in response to the output signal,
 - 15 - compressing a first signal parameter and generating a second compressed signal parameter,
 - generating a second compressed signal parameter in response to the reference signal,
 - determining a differential signal on the basis of the compressed
20 signal parameters, and
 - generating a quality signal by integrating the differential signal with respect to time and frequency,
- characterized in that the method furthermore comprises the following steps of
- 25 - converting at least two signal parameters into a third signal parameter, and
 - discounting the third signal parameter after determination of the differential signal and before generation of the quality signal.
9. Method according to Claim 8, characterized in that the method
30 comprises the following steps of
- converting at least a signal parameter at a first timepoint and at a first frequency and another signal parameter at a second timepoint and at the first frequency into a fourth signal parameter at the first frequency,
 - 35 - converting a further signal parameter at a first timepoint and at a second frequency and another further signal parameter at a second timepoint and at the second frequency into a further fourth signal parameter at the second frequency, and

- discounting the third signal parameter comprising the fourth signal parameter and the further fourth signal parameter before the differential signal is integrated with respect to time and frequency.
- 10. Method according to Claim 8, characterized in that the method
5 comprises the following steps of
 - converting at least a signal parameter at a first timepoint and at a first frequency and another signal parameter at the first timepoint and at a second frequency into the third signal parameter at the first timepoint, and
 - 10 - discounting the third signal parameter after the differential signal has been integrated with respect to frequency and before the differential signal is integrated with respect to time.
 - 11. Method according to Claim 8, 9 or 10, characterized in that the step of generating a second compressed signal parameter in response to
15 the reference signal comprises the following two steps of
 - generating a second signal parameter in response to the reference signal as a function of both time and frequency, and
 - compressing a second signal parameter.
 - 12. Method according to Claim 8, 9, 10 or 11, characterized in that
20 the step of generating a first signal parameter in response to the output signal as a function of time and frequency comprises the following two steps of
 - multiplying in the time domain a still further first signal to be generated in response to the output signal by a window function,
25 and
 - transforming the still further first signal to be multiplied by the window function to the frequency domain, which represents, after determining an absolute value, a signal parameter as a function of time and frequency.
 - 30 13. Method according to Claim 8, 9, 10 or 11, characterized in that the step of generating a first signal parameter in response to the output signal as a function of time and frequency comprises the following step of
 - filtering a still further first signal to be generated in
35 response to the output signal, which represents, after determining an absolute value, a signal parameter as a function of time and frequency.
 - 14. Method according to Claim 12 or 13, characterized in that the

step of generating a first signal parameter in response to the output signal as a function of time and frequency also comprises the following step of

- converting a signal parameter represented by means of a time spectrum and a frequency spectrum to a signal parameter represented by means of a time spectrum and a Bark spectrum.
- 5

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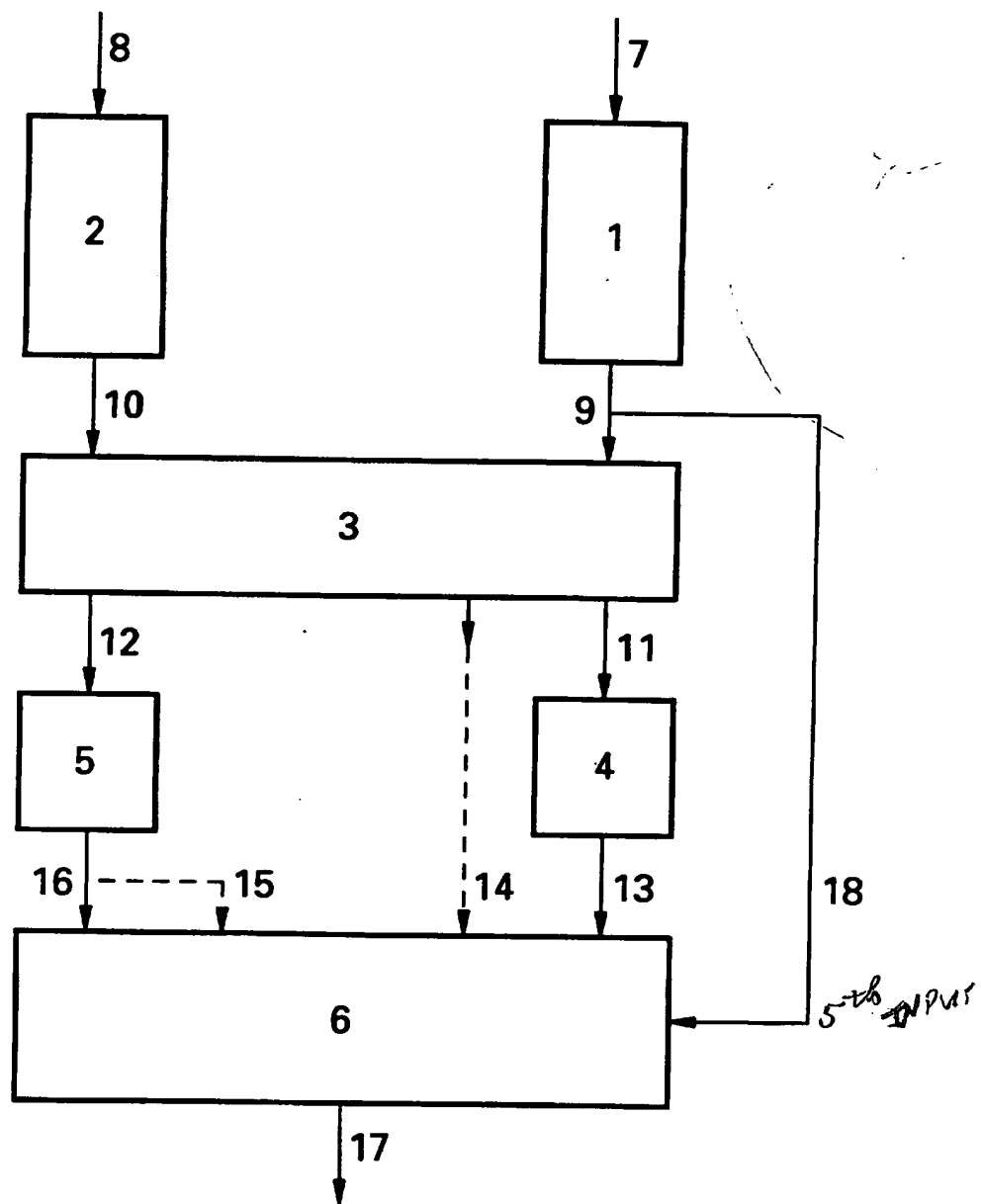


Fig. 1

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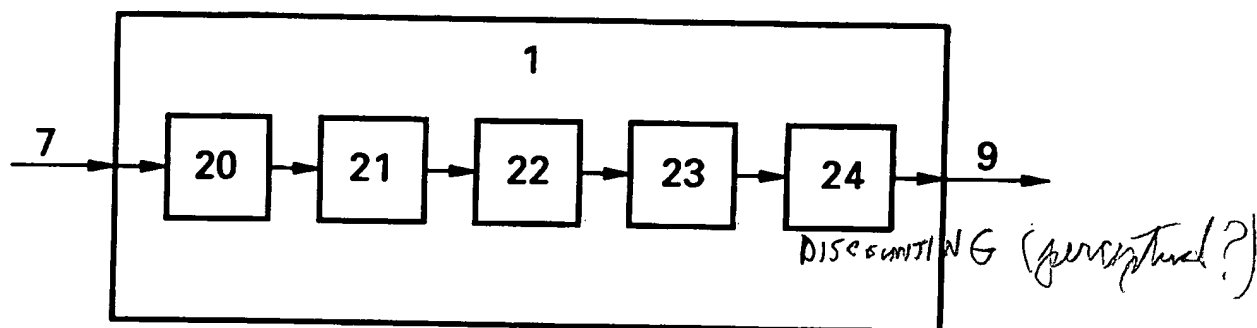


Fig. 2

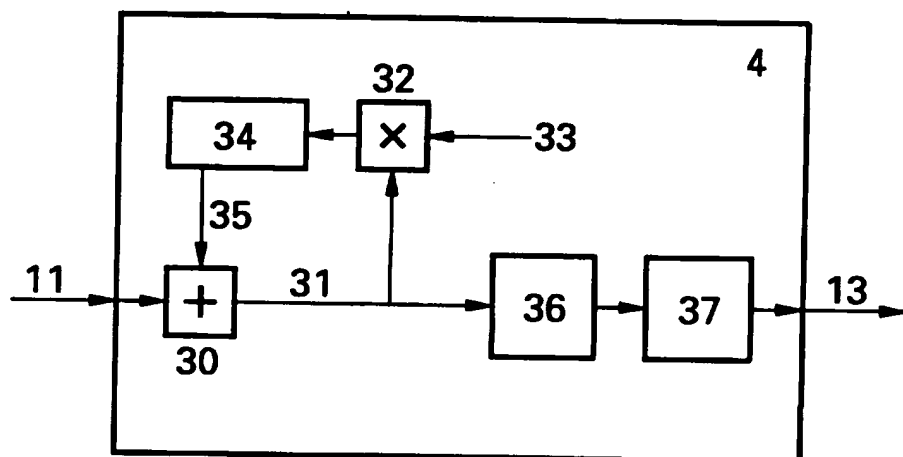


Fig. 3

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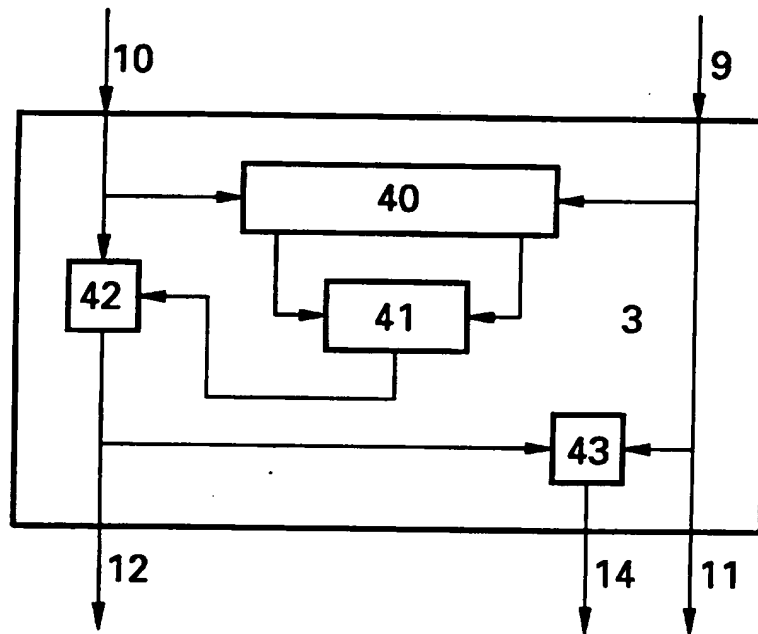


Fig. 4

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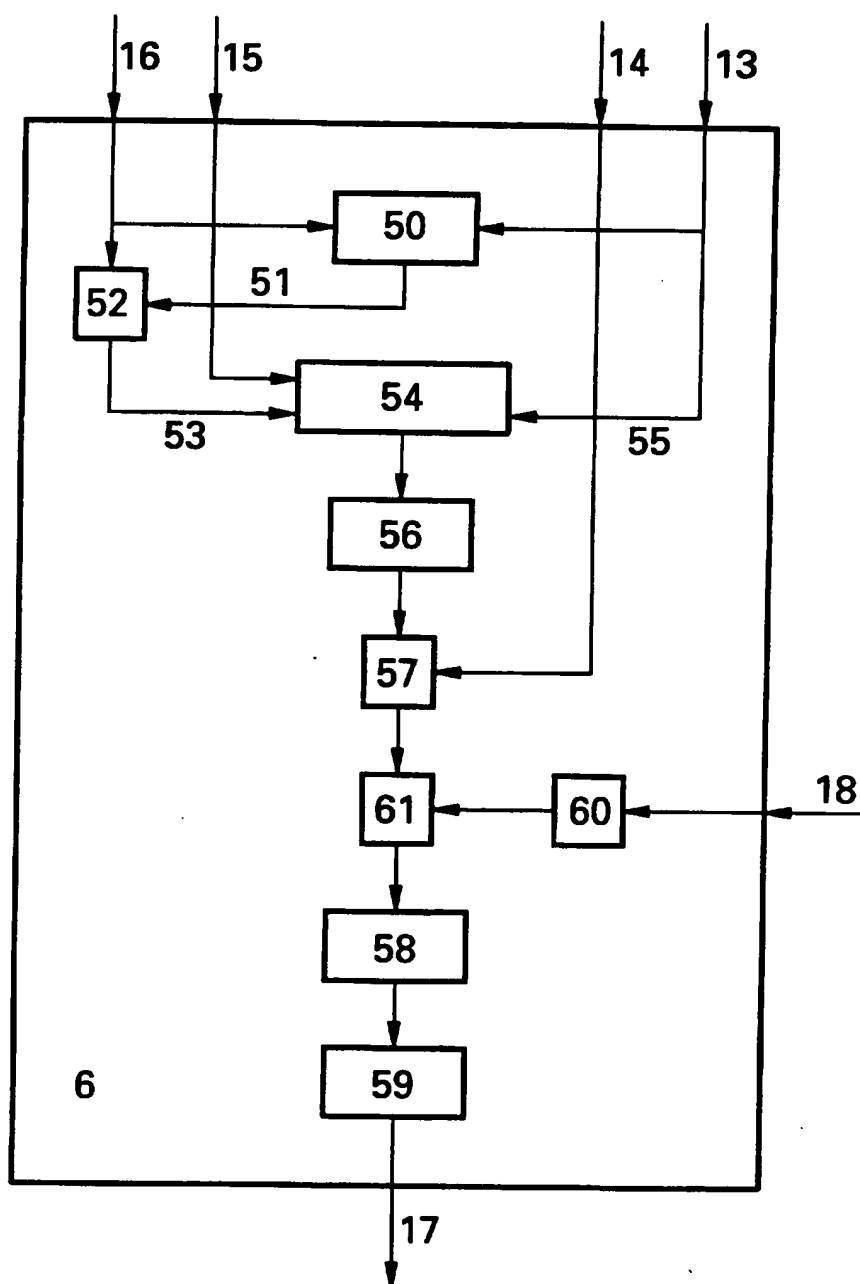


Fig. 5

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INTERNATIONAL SEARCH REPORT

International Application No

PC1/EP 96/00849

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04R29/00 G10L3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04R G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>JOURNAL OF THE AUDIO ENGINEERING SOCIETY, MARCH 1994, USA, vol. 42, no. 3, ISSN 0004-7554, pages 115-123, XP000568998 BEERENDS J G ET AL: "A perceptual speech-quality measure based on a psychoacoustic sound representation" see page 117, right-hand column, line 24 - page 120, left-hand column, line 6 --- -/--</p>	1,8

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

2 July 1996

Date of mailing of the international search report

3 0. 07. 96

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INTERNATIONAL SEARCH REPORT

International Application No
PC1/EP 96/00849

C/(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JOURNAL OF THE AUDIO ENGINEERING SOCIETY, DEC. 1992, USA, vol. 40, no. 12, ISSN 0004-7554, pages 963-978, XP000514954 BEERENDS J G ET AL: "A perceptual audio quality measure based on a psychoacoustic sound representation" cited in the application see page 964, right-hand column, line 4; claim 26; figure 971; example L ---	1,8
A	DE,A,37 08 002 (TELEFONBAU & NORMALZEIT GMBH) 22 September 1988 see column 1, line 51 - column 3, line 46 ---	1,8
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A	EP,A,0 627 727 (TELIA AB) 7 December 1994 see page 2, column 1, line 53 - page 2, column 2, line 30 ---	1,8
A	EP,A,0 417 739 (FUJITSU LTD) 20 March 1991 see page 4, line 3 - page 5, column 15 -----	1,8

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 96/00849

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US-A-4860360	22-08-89	NONE	
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EP-A-0417739	20-03-91	JP-A- 3098318 CA-A,C 2024742 DE-D- 69020269 DE-T- 69020269 US-A- 5224167	23-04-91 12-03-91 27-07-95 25-01-96 29-06-93